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ABSTRACT

This document describes a study that implemented active learning into a large introductory biology course. Five approaches were employed to promote the active learning: name badges, cooperative learning groups, large group discussion, in-class written responses, and written take-home assignments. The active learning approach takes more time than a traditional teaching approach and teachers who have tried this approach have struggled whether they teach at the K-12 grade level or at the college level. It is suggested that with either approach it is impossible to cover all material in the textbooks. (YDS)

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ED 467 605

THE CHALLENGE OF TEACHING BIOLOGY 100: CAN I *REALLY* PROMOTE ACTIVE LEARNING IN A LARGE LECTURE?

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When I returned to full-time teaching after nine years in academic administration, I spent a number of months reexamining my teaching practice. I realized that the students in my classes read a lot, and memorized a lot, but didn't always understand a lot. Often what I said in lecture was simply not sufficient to connect similar concepts across seemingly different topics. Many students expected lectures to follow the text closely, and did not easily absorb explanations and examples drawn from different chapters or from non-text sources. A typical student response at the end of the semester was that my lectures had often been disorganized and difficult to follow.

In the fall semester of 1995, I decided to see if any of the theory and practice associated with constructivist teaching could be used to advantage in a large lecture environment. I saw examples and read descriptions of how MCTP students were learning actively in laboratory settings and smaller classes, but I wondered whether active learning could be encouraged in a large lecture. I decided to experiment with my teaching practice in a large, introductory biology course (Biology 100). I asked to be given half of the class (approximately 240 students) as a single section for which I would be solely responsible. I felt strongly that the emphasis on a large body of factual knowledge did not provide students with the sense of wonder and excitement that scientists normally experience. I resolved to place a greater emphasis on questions, particularly those posed by students, and to use whatever means possible to challenge students to take greater responsibility for their own learning.

The summer before I started my experiment, I was lucky enough to meet Dr. Susan Blunck, who was being recruited as a science education specialist at UMBC. Her area of expertise is constructivist education. When I asked if she would collaborate with me in the MCTP program, she enthusiastically agreed. Moreover, she agreed to participate actively as a colleague and on-site observer in the classroom in the fall. At MCTP meetings that summer, Dr. Blunck and I gathered ideas and information from other MCTP faculty, and worked together to develop a set of somewhat radical changes in the way Biology 100 was finally taught that fall. Our goal was to employ a multiplicity of approaches to see if we could promote active (or participatory) learning in a large lecture environment.

The Course and Grading

Biology 100 ("Concepts of Biology") is a 4-credit, one-semester course designed primarily for beginning biology and biochemistry majors. It is traditionally offered by two, or occasionally three, tenure-track faculty members who take turns lecturing three times a week in 50-minute sessions to classes ranging from 240 to over 400 students. Students also meet in weekly, small-class discussion sections of 25 to 50 students led by graduate teaching

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assistants. The corresponding laboratory (Biology 100L) is taken as a separate course either simultaneously or in a subsequent semester. Students other than those majoring in biology or biochemistry (or allied health students for whom Biology 100 and 100L are also required), can enroll in the lecture course to meet a general education requirement in science without taking the associated laboratory course.

Traditionally, students in Biology 100 received a grade based entirely on their performance on four multiple choice exams consisting of 35–50 questions: the top scores earned on three out of four hourly exams, plus their score on the comprehensive final exam. In our new, active learning course, multiple choice exams were also administered, but these counted for less than a third of the course grade. Students were given three hourly midterm exams of ten questions each and a comprehensive final of twenty-five questions. All exams were open book. The top two midterm scores plus the score earned on the final exam determined 30 percent of a student's grade. Students were told that the remaining 70 percent of their final grade would be determined by their performance on written, take-home assignments (30 percent); by their participation both in the large class and in smaller, weekly discussion sections led by graduate teaching assistants (35%); and by their scores on oral and written quizzes administered during the discussion sections (5%).

Approaches Used to Promote Active Learning

We employed five specific approaches that we anticipated would make the large-lecture environment more personal, student centered and interactive. These were: (1) name badges; (2) cooperative learning groups; (3) large-group discussion; (4) in-class written responses; and (5) written, take-home assignments. An expanded description of each is given below:

1. Name badges. Large lecture halls and classes of more than 100 students seem impersonal—especially to freshmen. To help personalize Biology 100, we prepared individual, pin-on, name badges for each student at the beginning of the semester from the official enrollment list. I explained that each student should view him/herself as a member of a professional community and that, like scientists attending a professional symposium, they should wear their name badges whenever they were in class. It was noted that wearing name badges was a non-verbal means of participating.

One of the most immediate effects of the badges was that both the students and I could identify people in the class by name. When students raised their hand, they could be recognized by name without the need for a seating chart and assigned seating. This helped greatly to personalize the large lecture environment and encouraged more student questions and responses from a wider array of students than is typical in a large lecture course. Badges also helped me to learn students' names so that by the end of the semester I could recognize more than half of the students on sight even outside of the classroom.

Many students initially resisted wearing their name badges in class, but by the end of the semester most had become accustomed to the practice. Surprisingly few comments about name badges were made on student evaluations, and almost all were positive. One student wrote, "Name tags were a good idea. It is good to know that at least one instructor is interested in learning the names of his/her students!"

2. Cooperative learning groups. Research suggests that students learn higher order thinking skills when they can discuss their ideas and actively engage in dialog (Johnson, Johnson & Smith, 1991). Therefore, randomly selected cooperative learning groups, or teams, of up to four students were used to foster dialogue in Biology 100. In a class session at the start of the semester, four sets of cards numbered 1 through 70 were randomly distributed. One of the numbered sets was colored, and the 70 students who received these colored cards were asked to hold them up. Then all students whose numbers matched were asked to move together so they could easily converse. Groups were instructed to turn in the colored cards

listing the members' names and one sentence describing something unusual or uncommon that they all had in common. Finally, they were invited (but not required) to agree upon a team name.

Once formed, learning groups remained remarkably stable throughout the semester. Few students asked to switch teams. When given the opportunity at mid-semester to form new teams, the class overwhelmingly chose not to change partners. Team members were asked to sit near each other whenever they came to class, but sometimes individuals waited until I gave directions to start a small group activity before moving to sit with their other team members.

Team activities were varied throughout the semester as was the format of the response. All team activities took place during class and required either an oral or written response. In some cases I posed a short-answer question related to the topic at hand, and teams were asked to come to a consensus which would be reported to the class by a team spokesperson. At other times students were shown results of an experiment related to the day's topic, and then were asked to work together to develop a written team response that described and interpreted the results displayed. On still other occasions the class was presented with a concept question, and students were asked to provide individual written responses after a short period of team discussion.

For example, after a unit on cell respiration, the class might be asked to answer the following: "Do plant cells have mitochondria? Explain why or why not." Or, following a discussion of photosynthesis, I might ask: "How do plants that lose their leaves stay alive during the winter?" Or, as part of a unit on natural selection, students might be asked to respond to this question: "If an allele is recessive and is harmful, can selection eliminate it entirely from the population? Explain your reasoning."

Consistent with others who have used cooperative learning methods, we found that students enjoyed working together in small groups and reported that group work improved their understanding of the material. One student wrote on an end-of-semester evaluation, "I love being able to do group work because I am able to discuss my answers with other people." Another noted that as a non-native speaker of English she sometimes had difficulty with concepts such as osmosis, but could always turn to her group for help. When asked to assess their own contribution to group discussions, almost all students rated their participation as moderate to high. In contrast, when asked to evaluate the contribution of the other team members, students were typically quite candid and tended to be more discriminating in their assessments.

3. Large group discussion. Students were encouraged to ask questions in class, to reply to questions posed by me or by other students, and to respond to others' replies. In order to assure that students could hear each other speak, my wireless microphone was passed to any student who had a question or who wanted to respond to a question or statement. In previous classes, when I called on students for recitation, they were often reluctant to speak into the microphone I was holding. However, in the experimental section, such reluctance was much less evident, in part, because I only called on students who asked to be recognized. Perhaps more important was the fact that in this class I gave the students the microphone to hold during their responses. Thus, students easily and naturally obtained control of the means of communication with the entire class, and I could assume the role of listener rather than lecturer.

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Students were initially reluctant to speak out in a large lecture hall. Many who felt this way also resented the heavy weighting of

participation in the final course grade, since they assumed that speaking out in the large class was the only (or major) method of participation. I tried to correct this impression by reminding students they could also participate in the smaller, weekly discussion sections and by emphasizing that there were other, non-verbal means of participation. At about mid-semester, students who had become concerned about their participation grade complained that although they raised their hands in class, they were being recognized rarely or not at all.

I responded by providing a sign-up sheet at the end of class for all students who had raised their hand during class—whether or not they had been recognized. Not only did the number of complaints decline, but students did not abuse this unmonitored means of assessing their participation. About the same number of students signed the participation sheet as raised their hands in class—typically 20 to 30—and, aside from those who were already known to us as "high-frequency responders," names on the list differed from one class period to the next. I plan to continue this practice when the course is repeated.

On the course evaluation, students were asked, "What was the best part of the course and why?" Many responded that they appreciated the open atmosphere of the class and liked being able to hear different points of view. One student wrote, "The course involved lots of give and take between Dr. Sokolove and the pupils during the lecture. This made the class more dynamic. Also it provided an atmosphere where questions and a variety of perspectives were encouraged." Another appreciated " . . . the open discussions during which everyone had an opportunity to participate and share their ideas." A third commented, "I liked the fact that the students were able to give so much input. It made the class much more interesting. It was better than listening to lectures every day."

On the other hand, a few felt that the discussions in the large lecture were too disorganized and that there were too many people in class for participation. One student wrote, "The interaction takes away from the class. Straight lecture would be better. And [the instructor] should go over more chapters [in the textbook]." Another commented thoughtfully, "Although the discussions during lecture were great, we need to perhaps set aside [time for] a structured lecture in order to cover more information . . . "

4. In-class written responses. Some education specialists have emphasized the need to get written feedback from students no matter the size of the class. In Biology 100 students were required to bring to every class session a laboratory research notebook (published by Jones & Bartlett; Sudbury, MA) in which they could write their responses and comments. The notebook had numbered, duplicate pages of carbonless paper that allowed students to retain a permanent copy of everything they wrote. A notebook page might be turned in to ask questions about the day's material, or to reply to a short-answer question. Other examples of how the notebook was used include responding to informal survey questions (such as "What would you suggest to improve this course?"), and writing one-minute papers relating one main point that they learned in class that day along with a question that they had about that day's topic.

The advantage of the notebook was that it offered a vehicle for shy students to communicate with the instructor without having to raise their hands and speak out, or to remain after class to ask questions, or to make an appointment to meet with the instructor. As the semester progressed, the notebook was used more and more frequently to facilitate non-verbal, in-class student input. When students wrote down their questions, responses, and comments, they were generally thoughtful and explicit in expressing themselves.

Reading and responding to one or more excellent questions from students at the beginning of class was sometimes used to provide positive feedback on student questions and to exemplify what I considered to be a good question. Students' written responses were also helpful in identifying misconceptions, misunderstandings, or confusion about the

material so that these could be addressed in the subsequent class period.

5. Written, take-home assignments. There were three take-home assignments during the semester, each of which focused on an application-oriented question. For example: "You are a track star scheduled to compete in a 1,500 meter race next week. Your coach tells you to 'load up' on carbohydrates the day before the track meet so that your body will have plenty of energy in reserve for the race. *Is the coach correct in her advice? Why or why not?* Cite evidence to support your position."

For each assignment, students were asked to provide a three-part response of up to five typed pages: Part I asked students to describe what research sources they had consulted and explain why these had been chosen, and also to list any resources that were not consulted and to explain why these had not been used. Part II asked for a response to the question that had been posed with appropriate citations. Part III asked students to pose two questions of their own that resulted from the research they had done.

All papers were read and graded either by me or by graduate teaching assistants using a rubric based upon the following grading approach. For each section of the paper that met a minimum level of acceptability, the student was guaranteed a "good" grade of B-(e.g., 8 out of 10 possible points). There were no correct or incorrect responses. To be minimally acceptable, a paper had to demonstrate an honest effort by the student, and each part of the response had to be complete (all directions followed) and readable (clearly organized with few spelling or syntax errors). Additional points could be earned if a student displayed extra effort and thoughtfulness in his/her response; points could be lost if a student failed to follow fully the directions provided—for example, noting which research sources were consulted (books in the library, my high school track coach, etc.), but failing to explain why these were used and others (the World Wide Web, sports or nutrition journals, articles in the popular press, etc.) were not.

Take-home assignments served to initiate discussion about the types of information sources that are available and about the reliability of the information they provide. Students typically reached different conclusions about the answer to the question posed in the assignment. These were aired in class discussion to illustrate the importance of scientific discourse and to allow students to gain experience in defending the interpretation of their research findings. Take-home questions were assigned that could be readily related to one or more biologically important concepts or topics. In the case of "carbo-loading," such topics might include digestion, cellular respiration and muscle energetics. Students could thereby learn key facts and concepts in an applied context with guidance from the instructor, rather than feel they needed to memorize them from lecture notes or the textbook only because "they might be on the next exam."

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The response of students to take-home assignments was generally positive, although one student advised us to " . . . do away with those silly research papers." Most felt that the assignments provided a chance to engage in self-directed learning and to demonstrate what they *could do* as opposed to what they *could not do*. One student commented that, "The take home assignments were a help in the understanding of certain topics." Another wrote, "The take home questions were a good opportunity for students to demonstrate knowledge without being in an exam situation." A third noted, "I learned the most from the take-home assignments, researching and discovering information on my own. I feel there should be twice as many take-home assignments as there was [sic]! They are great practice [for writing] and they are very helpful in learning on our own! I feel it is important to learn on your own—it really sinks in that way."

What Have We Learned?

"He makes us think." This is how one student in fall 1995 introductory biology responded to the following question on the course evaluation questionnaire: "What personal qualities did this instructor have which hindered his/her teaching?" Another student answered, "He doesn't answer questions directly and lets students find it for themselves." A third replied, "He openly stated he didn't know. Made opinions about him skeptical about his abilities [as an instructor]."

Dr. Blunck and I have learned a number of lessons that we hope will allow us to improve our efforts to promote active learning in introductory biology. First, we recognize that students do, indeed, have different ways of learning, and we will continue to provide choices both within class and between classes for those with different learning styles. Within the class, we have used multiple teaching/learning approaches and will continue to do so. But we will emphasize at the outset that there are many ways for students to succeed besides simply doing well on exams or speaking up in lecture.

Based on our findings, we will refine some approaches, modify others, and eliminate still others (see examples of planned changes under "Work in Progress" below). We may also add new approaches such as "concept tests" that show much promise (Mazur, 1995). We will also respect those students who feel they learn best in a more familiar lecture course. When the course is repeated, such students will be advised that they can enroll in a different section of Biology 100 that is offered by the department using a more traditional approach.

Second, we have confirmed that cooperative learning is as fruitful in professional development as it is in the classroom. The collaboration between Dr. Blunck and me was, I think, essential for effective modification of my teaching. It has often been said that student evaluations are of limited use in assessing the quality of teaching. Nevertheless, there are few instances at the college level where other methods of assessment, such as peer review, are regularly and conscientiously employed. Even fewer are cases in which teaching practice is assessed by an experienced field evaluator on an ongoing basis. The model of continuous improvement in teaching requires continual feedback. In reforming Biology 100, we have found that sharing the experience of a professional science education specialist (Dr. Blunck) and a scientist instructor (me) has allowed us to meet common educational goals that could not be achieved by relying on student assessments alone. In the case of Biology 100, regular, constructive input from Dr. Blunck was instrumental in promoting rapid and effective changes in my teaching practice.

Third, we have found it possible to implement a variety of active learning approaches in a large-lecture environment, but we cannot yet stipulate which of these has been more (or less) effective in promoting understanding of basic concepts. From the perspective of students, it appears that cooperative learning groups were the most helpful of the methods employed. Virtually all students who commented on small group discussion claimed that it significantly aided their understanding, and no student commented negatively about team learning. However, an approach such as large group discussion that elicited positive responses from many students, was viewed by others as a distraction. While a large number indicated that the best part of the course was class interaction and having input from the students in the class during lectures, one student commented, "Sometimes class seemed like a talk show." A significant fraction of the class felt that there should have been more structure, less class participation, and more text book related material on exams]. Clearly not all agreed with the student who wrote, "I loved this new teaching technique. I learned more in this class than I have in any science course. Everybody could benefit from this change if they don't resist it."

Work in Progress

Dr. Blunck and I regard our efforts as a "work in progress" and not as a finished product. Students who completed the semester did not necessarily appreciate being asked to participate in their own learning and a number

continued to prefer traditional ways of learning biology. Some of the changes we plan to make when the course is repeated will be in response to student input, while others will be new. Among the changes we plan are the following:

- Students will be given more explicit information about what they can do to participate during class so that speaking out in front of the whole class is not viewed as the sole means of participating.
- Additional wireless microphones will be purchased so that the instructor does not have to race around the lecture hall in order to hand the microphone to a student.
- More effort will be made to provide structure by providing a short list of the major concept or concepts we hope to cover each week together with a list of the relevant text chapters.
- Cooperative learning groups will be employed more frequently during class using a wider range of activities.
- Peer evaluation of written take-home assignments will be used in conjunction with a grading rubric that will be discussed (and possibly modified) before assignments are made.
- Students will be given the option of purchasing a higher level textbook in lieu of the "required" text, but those who choose this option will need to assume responsibility for determining what sections of that text relate to the concept list.

What About Content?

Virtually all of the teachers who have tried to promote active learning in their classrooms, whether in grades K–12 or at the post-secondary level, have had to struggle with the fact that active learning approaches take more time and consequently reduce the time available in class for "coverage" of material. I, too, have had to struggle with the coverage issue in Biology 100. However, I recognized at the outset that even in a traditional lecture course, it is impossible to cover within a single semester all the material contained in even the least challenging introductory textbook. Thus, it is always the case that regardless of who teaches the course (or, perhaps, *depending* on who teaches), some topics will be covered and some not. In our case, I tried to reduce the number of topics to a core of essential concepts. However, it will take many iterations of teaching Biology 100 before I am comfortable with the choices. No doubt even these choices will change with time and experience—and after many discussions with other faculty members in my department.

National groups such as the American Association for the Advancement of Science and the National Research Council have been engaged in developing new guidelines for science education. A consistent finding expressed in these efforts is that students learn best when exposed to environments that encourage reflection, self-directed and inquiry-based learning, and higher order skills that go beyond memorizing items of information (AAAS, 1993; NRC, 1996; see also, Yager, 1993). Content issues are not ignored. Indeed, almost half of the NRC's *National Science Education Standards* is devoted to content standards. However, the emphasis in these content standards is shifted in important ways. One shift is from expecting students to know scientific facts and information to expecting them to understand scientific concepts and develop abilities of inquiry. Another major shift is from covering many science topics to studying a few fundamental science concepts (*Standards*, p. 113).

I recognized at the outset that even in a traditional lecture course, it is impossible to cover within a single semester all the material contained in even the least challenging introductory textbook.

Still, there are many who continue to wonder, are there any "objective" data regarding student learning when these standards are applied in the college classroom? Can students really learn "enough" even though one covers less

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material? One way Dr. Blunck and I attempted to determine whether students in our student-centered, active-learning version of Biology 100 had been "short changed" was to examine their performance on the same final exam questions given to students in the traditional lecture section taught that semester. Whether we examined average performance on the entire set of questions or looked at the percentage of the class that answered each question correctly, we found that students in the active learning section performed *as well as or better than* the students in the traditional lecture section. The following student comment captures our subjective impression of how well students learned: "I liked the new format. I tried to take this class a year ago and was confussed [sic] and bored senseless. I picked up a lot this time and I enjoyed it!"

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